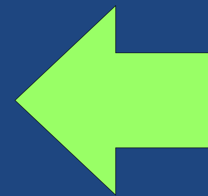
Arrays and Dynamic Memory

Readings Topics:

Pointers

Arrays (some)

Dynamic Memory



Suggest reading text if possible.

Material is more advanced.

Dr. Donaldson's notes: http://www.cs.sfu.ca/CourseCentral/130/tjd/chp9notes.html

Topics

1) How can we store many elements (without a vector)?
2) How can we get and manage extra memory?

Arrays

- Array Declaration:
  - Specify type of elements, and # elements.
    int daysPerMonth[12];
  - Arrays are quite similar to vectors, but can be faster, and once created..

- Directly access an element:
  - For N elements use indices 0 to N-1
  - daysPerMonth[0] = 31; // January
- Ex:
  - daysPerMonth[11] = 31; // December
  - int a = daysPerMonth[1]; // February
  - cout << daysPerMonth[1]; // Outputs 28
  - cin >> daysPerMonth[9]; // Read in oct.

Array
daysPerMonth

	Idx	Val
Jan	0	31
Feb	1	28
Mar	2	31
Apr	3	30
May	4	31
Jun	5	30
Jul	6	31
Aug	7	31
Sep	8	30
Oct	9	31
Nov	10	30
Dec	11	31

Array example

```
#include <iostream>
#include <iomanip>
using namespace std;
int main() {
	// Create the arrays for day names and hours per day.
	const int DAYS_PER_WEEK = 7;
	float hoursWorked[DAYS_PER_WEEK];

	// Ask user for time worked.
	for (int i = 0; i < DAYS_PER_WEEK; i++) {
		cout << "Hours worked on day " << i << ": ";
		cin >> hoursWorked[i];
	}

	// Calculate total hours
	cout << "Week summary:\n";
	cout << fixed << setprecision(1);
	float totalHours = 0;
	for (int i = 0; i < DAYS_PER_WEEK; i++) {
		cout << i << " = " << hoursWorked[i] << " hours.\n";
		totalHours += hoursWorked[i];
	}
	cout << "Total hours: " << totalHours << endl;
}
```

```
Hours worked on day 0: 0
Hours worked on day 1: 1.5
Hours worked on day 2: 26.9
Hours worked on day 3: 8.2
Hours worked on day 4: 1.6
Hours worked on day 5: 0
Hours worked on day 6: 1
Week summary:
0 = 0.0 hours.
1 = 1.5 hours.
2 = 26.9 hours.
3 = 8.2 hours.
4 = 1.6 hours.
5 = 0.0 hours.
6 = 1.0 hours.
Total hours: 39.2
```


= hoursWorked.cpp

In-Class Example

- Write a program which:
  - reads up to 10 floats from the keyboard
  - but which stops when the user enters a 0. (Called a sentinel: a value which marks the end)
- It must then:
  - display the values to the screen

Possible solution

```
#include <iostream>
using namespace std;
int main()
{
	// Create the array
	const int MAX_SIZE = 10;
	float data[MAX_SIZE];

	// Populate the array
	cout << "Enter up to " << MAX_SIZE
		<< " values (0 to exit):\n";
	int count = 0;
	for(count = 0; count < MAX_SIZE; count++) {
		// Get the next value
		float newValue = 0;
		cin >> newValue;

		// Are we done?
		if (newValue == 0) {
			break;
		}

		// Store in array:
		data[count] = newValue;
	}
```

Continued

```
	// Print out all the values:
	cout << "\nData:\n";
	for (int i = 0; i < count; i++) {
		cout << i << ": "
			<< data[i] << endl;
	}
}
```

```
Enter up to 10 values (0 to exit):
10
15.112
20.222
0

Data:
0: 10
1: 15.112
2: 20.222
```


= arrayEntrySentinel.cpp

Passing a full array

- Need two things to pass an array to a function:

Function can handle any size of array.

Must tell it the size of the array separately.

When calling, pass in the array (no []!), and size.

```
void showAllElements(char arr[], int size) {
    cout << "Displaying all elements:\n";
    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;
}
```

```
int main () {
    const int N = 5;
    char myArray[] =
        {'H', 'e', 'l', 'l', 'o'};

    // Pass the whole array.
    showAllElements(myArray, N);
    ...
}
```

```
Display all elements:
H e l l o
```

Pass array by Pointer

- Passing an array to a function passes..
  - It is not a copy of the array:
    it is the address of the real thing.
  -

```
void zAllElements(char arr[], int size) {
    for (int i = 0; i < size; i++) {
        arr[i] = 'z';
    }
}
```

```
int main () {
    const int N = 5;
    char myArray[] =
            {'H', 'e', 'l', 'l', 'o'};

    // Pass the whole array.
    zAllElements(myArray, N);
    showAllElements(myArray, N);
    ...
}
```

Arrays and Pointers

- Arrays & pointers are similar:
  - Array names can be..
  - Pointers can be..

```
int costs[] = {0, 10, 20, 30, 40};
int *pValue = costs;        //..

cout << "Array:    " << costs << endl;
cout << "Pointer:  " << pValue << endl;

cout << "costs[0]: " << costs[0] << endl;
cout << "*costs:   " << *costs << endl;

cout << "pValue[0]:" << pValue[0] << endl;
cout << "*pValue:  " << *pValue << endl;

for (int i = 0; i < 5; i++) {
    cout << pValue[i] << ", ";
}
```

```
Array:     0x7fff87968010
Pointer:   0x7fff87968010
```

```
costs[0]:  0
*costs:    0
```

```
PValue[0]: 0
*pValue:   0
```

```
0, 10, 20, 30, 40,
```

Arrays vs Vectors

- Arrays and Vectors have a similar purpose:..
  - Many problems which could be solved with one can also be solved with the other.

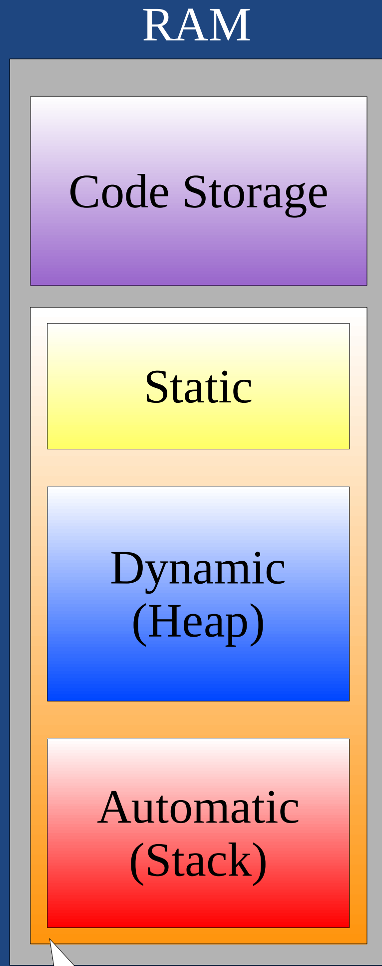
	Array	**Vector**
Data Type	Fundamental type to C++ (and C) language	A class in the C++ standard library ("using namespace std;")
Change Size?	Fixed size	Dynamically resizes
Code to create	int myArray[10];	vector<int> myVect;
Set element	myArray[0] = 42;	myVect.at(0) =42 or myVect[0] = 42
Add extra element	Impossible	myVect.push_back(101);
Access element	cout << myArray[0];	cout << myVect.at(0); cout << myVect[0];
Ask it for its size	Impossible	cout << myVect.size();
Pass to function	Pass as a pointer (array)	By value, by ref, or by pointer

Dynamic Memory

Why do we need this?
Doesn't vector do everything we need?

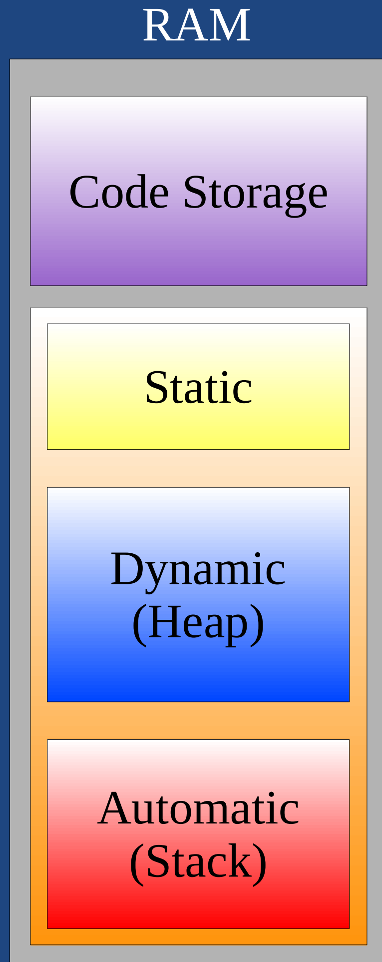
Vector's great! However...
- There's more to software development than vector
- Vector had to be implemented using something!

Memory



- Code Storage
  - Also called "text"
  - Stores the..
- Data Storage
  - Stores the..
  - Types: Static, Dynamic, Automatic.
- Static Memory
  - Holds..
  - Values initialized when program starts.

Memory: Automatic



- Automatic Storage
  - Local variables allocated..
  - When function exits, it pops its local variables off the stack..
    - Space reused for next function call.
  - Calling a huge number of functions will overflow the stack (crash the program).

Example: Bad Recursion

```
void crashProgam() {
    crashProgram();
}
```

A function that ..

Returning a new array

- How can a function return a new array?
  - You can't return an array, but you can return a pointer
  - Here's the first (bad) try!

```
float* makeArrayOfNumbers(int size)  {
    float arr[size];

    for (int i = 0; i < size; i++) {
        arr[i] = i;
    }
    displayArray(arr, size);
    return arr;
}
```

```
0 1 2 3 4
0 4.59163e-41 0 0 0
```

```
void displayArray(float arr[], int size)  {
    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;
}

int main() {
    const int SIZE = 5;
    float *myArr =
        makeArrayOfNumbers(SIZE);
    displayArray(myArr, SIZE);
}
```

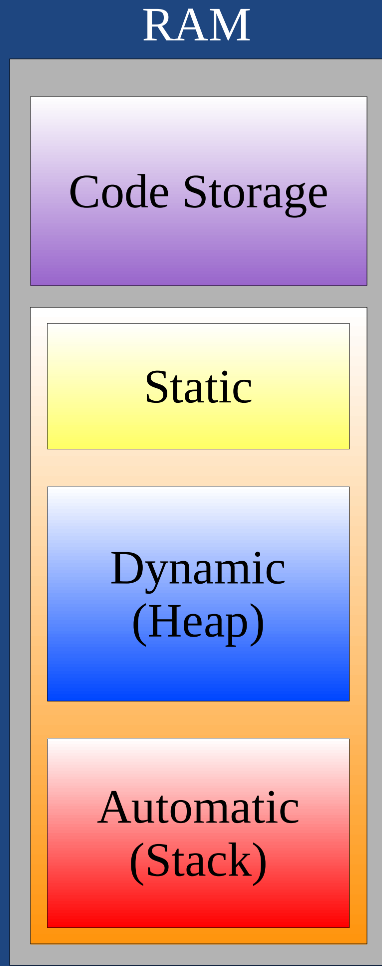
What went wrong?

- Never..
  - Local variables are popped off the stack when the function finishes.
  - All pointers to popped-locals become..

```
float* badIdea(int size)  {
    float arr[size];
    // ...
    return arr;
}
```

- How can we get some memory which is not on the stack?
  - So it will not be popped when the function exits?

Memory: Dynamic



- Dynamic Storage
  - Allows for:
    -
    - gives program control over..
  - Allocate using..
    Deallocate using..
  - In separate memory region..

What would happen if we "dynamically" allocated on the stack instead?

Dynamic Arrays

```
void displayArray(float arr[], int size);

float* makeDynamicArray(int size)
{
      float *arr = new float[size];     ..
      for (int i = 0; i < size; i++) {
            arr[i] = i;
      }
      displayArray(arr, size);
      return arr;                       ..
}

int main()
{
      float *myArr = makeDynamicArray(SIZE);     ..
      displayArray(myArr, SIZE);
      delete[] myArr;                       ..
}
```

- Use dynamic allocation to create an array in the heap.
- Return a pointer to this array.
- Use the array like a normal array.
- Later, we must free the memory using delete.

Dynamic Allocation

- new

```
double *heightArr = new double[100];
```

  - new allocates space from heap.
  -

- delete

```
delete[] heightArr;
```

  - delete releases (frees) memory.
  - Must free memory..

      - Can only free it once!

Returning allocated space

```
int* getRandArray(int n)
{
	// Allocate space
	int* pArr = new int[n];

	// Initialize data
	for (int i = 0; i < n; i++) {
		pArr[i] = rand() % 100 + 1;
	}

	return pArr;
}
```

```
int main()
{
	const int SIZE = 10;

	// Get the array of data
	int* pData = getRandArray(SIZE);

	// Use the allocated memory
	cout << "Data: ";
	for (int i = 0; i < SIZE; i++) {
		cout << pData[i] << " ";
	}
	cout << endl;

	// Free the memory to
	// avoid memory leaks.
	delete[] pData;
	pData = nullptr;
}
```

= useNew.cpp

Pointers

- Pointers:
  - Pointers are often allocated..

    - Pointer destroyed when it goes out of scope.
    - When pointer destroyed, data it points to..

- Dynamic Array
  - Allocated on the heap, pointed to by a pointer.
  - Must call delete[ ] on the dynamic array regardless of when pointers are destroyed.

Summary

- Arrays are like vectors, but you manage the memory.
  - Arrays are pointers; pointers are arrays.
- Dynamic memory
  - Use new to allocate array on heap;
  - Use delete[ ] to free the memory.